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A COMPARISON OF THE DETECTION RATES FOR INFRARED AND VISUAL IMAGERY OF A PERSON HOLDING AN RPG (U)

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ABSTRACT (U)

(U)   Detection of potential threats that are camouflaged or concealed is important not only for military acquisition problems but, also for crowd surveillance as well as tactical use such as on border patrols.   Imaging and display technologies that take advantage of photo-simulation and sensor fusion are discussed in this paper. A comparison of the detection rates of visible, infrared (IR) and sensor-fused imagery of scenes that contain a Rocket Propelled Grenade (RPG) were made. Image fusion was achieved using a Gaussian Laplacian pyramidal approach with wavelets for edge enhancement. Three types of images were also compared in terms of better detection of concealed weapons.

Objectives (U)

(U)   Objective of this experiment was to evaluate the detection rate of three different types of imaging techniques. Also to apply entropy, clutter and textured clutter metrics to the image and find a relationship to the detection rate. A linear model using SPSS was also achieved.

(U) Image preparation and subject recruitment

(U)   Images were taken with a visual and IR camera. For visual images, the Sony Digital camcorder (DCR-TRV 240) was used. An OMEGA (Indigo Systems Corporation, 7.5 – 13.5 µm, 164H x 128V, uncooled micro bolometer sensor array) system was used which was connected to the Sony camera for image capture. Images were initially recorded on Hi8 digital tapes. Each image was digitized with the Fast-studio software. Per each shooter images, the individual image was sized and cropped to match the location of the target (shooter) on pixel by pixel bases. Fused images were prepared using the Fusetool application in Matlab based program.   30 civilian subjects were randomly selected from the employee population of TARDEC. Each subject took the RPG detection test, and ranking the quality of images test.

(U) Experimental procedure

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(U)   Test No. 1: RPG detection test.

(U)   The test consisted of 192 images in a random order (4 shooters x 2 shots x 3 image type x 2 target/no target x 4 image condition). Four different shooters posed for the RPG fire. Images were taken before the RPG fire and after the RPG fire (consist of eight image sets). There are three image types (IR, visual, and fused images). For the original IR and visual image sets, no target images were made with Photoshop utility then no target fused images were made. The original image set was considered as clear condition. To add the difficulty of the detection, noise was added to the clear condition image sets. Also for similar manor, contrast was adjusted and the brightness was adjusted.

(U)   The test was done on a flat panel monitor. Each image was shown for 1 second and then random noise pattern was shown with question. The test subject was asked to click "Yes" or "No" button, depending on whether he could see the RPG in the picture or not. After clicking the answer it is asking question whether the subject is ready to view the next image. After all 192 images were shown randomly the subject was requested to enter some comments. "Yes" or "No" answer was recorded per image and response time was also recorded (time from the "Yes" or "No" button shows up to the actual mouse clicking on the answer)...
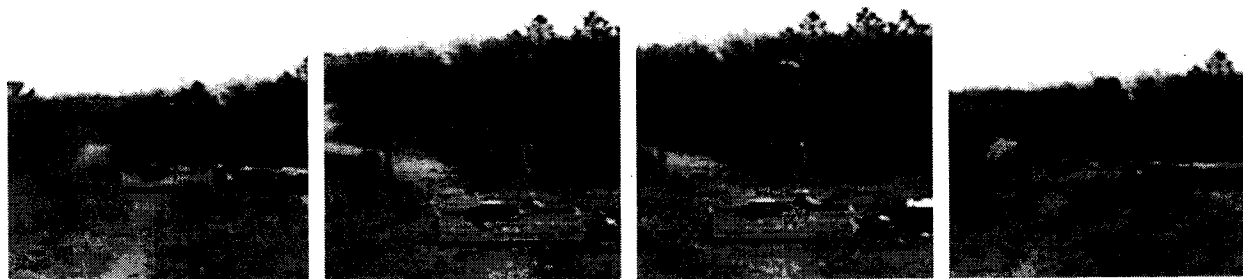

Figure 1. (U) Visual images of shooter1, 2, 3, and 4 respectively
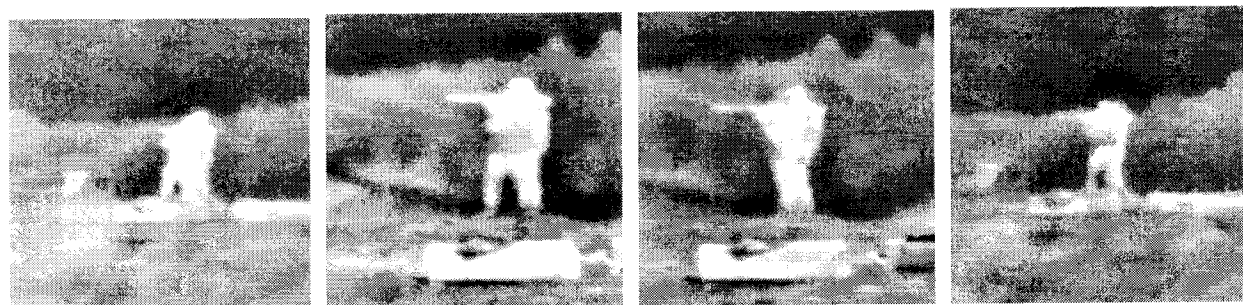

Figure 2. (U) IR images of shooter1, shooter 2, shooter 3, and shooter 4 respectively

(U)   Test No. 2: Visual preference of three types of images: visual, IR and fused.

(U).   30 of same subjects who took the test No.1 were also tested for the ranking quality of the image test. Image sets were consist with 32 sets of three combined images (visual, IR and fused image with RPG in order). Image sets consisted of four shooters with before and after the shot

with all image conditions. Only images with RPG were used in this test. The question that was shown in the monitor was "Which image is better in terms of detecting the RPG?" They were asked to rank images in the set by clicking the preferred image area. The response was marked as the image number (IR = 1, visual = 2, fused = 3) in order in the response file. Figure 3 shows the example sets for the shooter 1 before the shot (A and B), and after the shot (C and D).

(A)   (B)

(C)   (D)

Figure 3. (U) Shooter 1 with RPG combined image of visual, IR, and fused
(A) clear condition, (B) noise added, (C) brightness adjusted, (D) contrast adjusted

(U)   Summary of Test Data.

(U) Test No 1.

(U)   The probability of detection (PD) of the RPG was calculated as a ratio of correct answers to the total number of target pictures (images with people with RPG, 96 images total). Detection rate was highest for the IR image due to the high contrast level between the RPG and the background. For the visual image, the contrast ratio between the RPG and the tree background was very low; it gave the lowest detection rate over the three image types. Detection rate of the noise added image was significantly low compared to the other effects. But the rate of detection rate drop of the fused image was relatively slow compare to the IR and visual images.
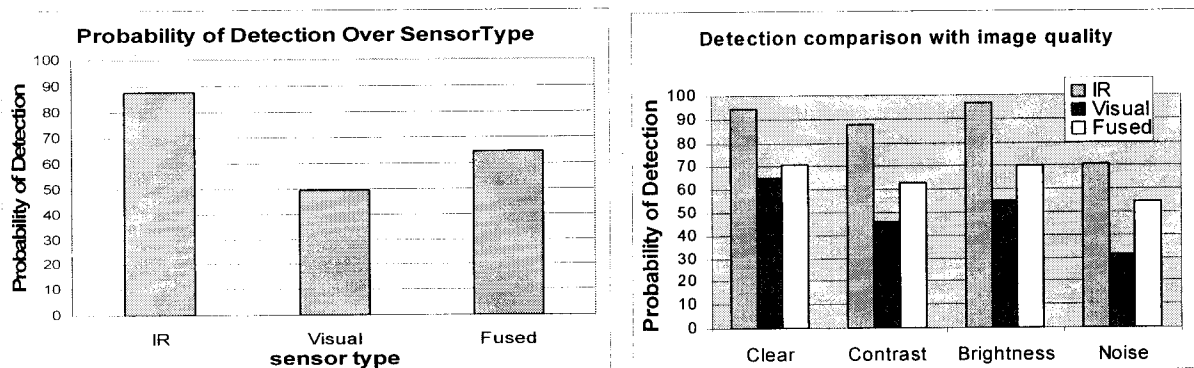

Figure 4. (U) Comparison of the probability of detection over sensor types

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(U)   Also entropy, clutter, and textured clutter metric were calculated over individual images. Figure 5 is the graph of each entity averaged over four shooters. The entropy value of different types of sensor behaved similarly over each image conditions. Both clutter and textured clutter behaved similarly for the image conditions which giving the low value for the contrast adjusted image. Also the visual image had the highest textured clutter and clutter value for the same image conditions for both textured clutter and clutter metrics.
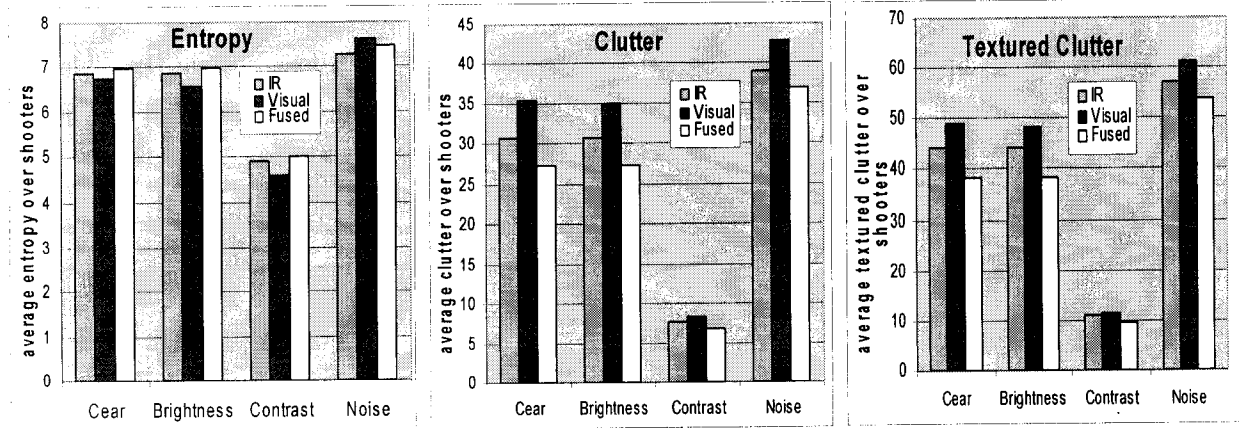

Figure 5. (U) Entropy, textured clutter, clutter averaged over shooters

(U)   The entropy of an image is a measure or the information content, in terms of gray scale levels and is also related to the texture if the image. The maximum value the entropy metric can take on is eight and the minimum is zero. The equation used for the calculation of the entropy (ref.1) is shown below,

$$H = \sum_{g=0}^{L-1} P(g) \log P(g)$$

Where P(g) is the probability of a gray value g, and the range of g is [0, 1, 2, ..., L-1].

(U)   The clutter metric used in this paper is a metric defined by Schmeider-Weathersby (SW) (ref. 2). The SW clutter metric is written as following.

$$\text{Clutter} = \sqrt{\sum_{i=1}^{N} (\frac{\sigma_i^2}{N})}$$

Where σ_i is the variance of the ith cell and N is the number of cells. The SW clutter metric divides the image into a number of cells, each of which are scaled to represent twice the longest dimension of the target, and then the variance of each cell is divided by the total number of cells.

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(U)   The textured clutter metric was modified from the clutter metric. The standard clutter SW definition of clutter was modified to include image texture by calculating the gray scale texture for each cell and then using that texture in place of the variance (ref. 3). The textured clutter equation is as following:

$$Clutter = \sqrt{\sum_{i=1}^{N} \frac{\frac{1}{N_\theta}\sum_\theta T_i(j,k,r,\theta)}{N}}$$

Where

$$T(j,k,r,\theta) = \sum_{a=0}^{L-1}\sum_{b=0}^{L-1} P(a,b;j,k,r,\theta)$$

Where a and b are any two gray-scale values at any pixel (j,k) in the image matrix, r is the step size, and q is the direction of the steps (q equals 0 means stepping horizontally). P is the fraction of the total number of steps whose end points are the gray-scale values a and b, respectively. The mean texture is defined as following:

$$M_T(j,k,r) = \frac{1}{N_\theta}\sum_\theta T(j,k,r,\theta)$$

(U)   Figure 6 below shows a good correlation of entropy of image with detection, as well as good correlation of clutter and textured clutter with detection. As we can see from the table in the right hand side, the correlation coefficients are close to 1. In this test, textured clutter matrix gave the best correlation to the detection rate.

Shooter	Entropy	Clutter	Textured Clutter	% DET
Shooter 1	6.4	22.1	31.6	49.9
Shooter 2	6.7	33.0	46.6	80.8
Shooter 3	6.7	32.7	46.8	91.5
Shooter 4	6.2	21.4	30.4	46.5

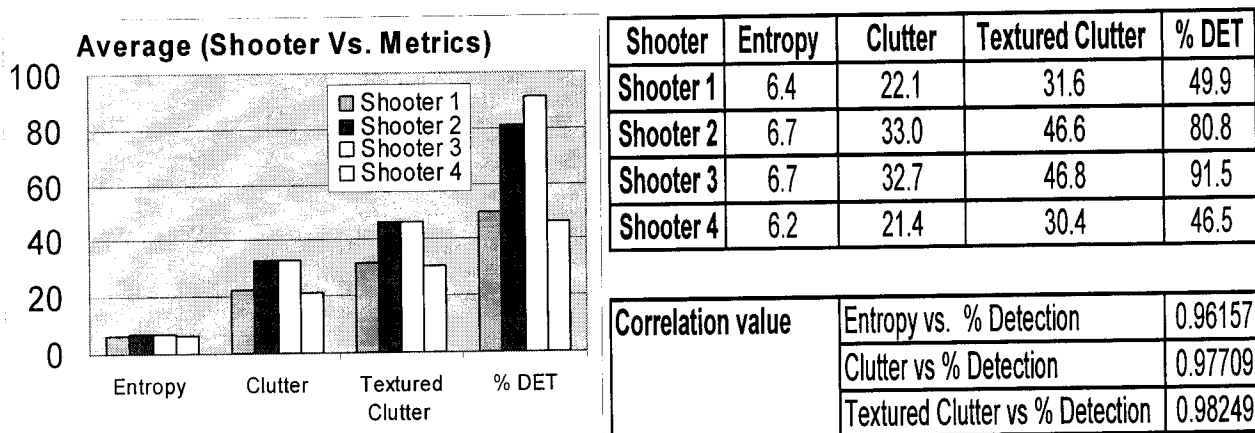| Correlation value	Entropy vs. % Detection	0.96157
	Clutter vs % Detection	0.97709
	Textured Clutter vs % Detection	0.98249

Figure 6. (U) shooter vs. metrics comparison

(U)   We wish to investigate whether there are differences in sensor type effect the ability to detect threats. Two factors that will be considered will be sensor type shooter profile. An experiment was designed using three levels of sensor and four levels of shooter. The level of effect was held at four, time at one, and threat at one. The response variable is whether the subject correctly identified a shooter with an RPG. A rank transformation was applied to the

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response variable. This will be our dependent variable. Once a subject is chosen, the order in which the twelve treatment combinations are randomly determined. Furthermore, subjects differ in their skill and ability to detect threats. Thus, we shall use subjects as blocks. Now, we have a 3 X 4 factorial experiment in a randomized complete block.

(U)   The complete analysis of variance for this experiment is summarized in Table 1. The first column of the table labeled Source is the effect or factor(s) in the model. The second column shows the type III sum of squares (ref.4) which is often used for an unbalanced model with no missing cells. The third column labeled "df", shows the degree of freedom for each sum of squares. The Mean Square column shows the mean square of each effect. This is obtained by divide the sum of squares of each effect by the degrees f freedom for each effect. The fifth column s the F statistics and shows the F statistic for each effect. The F statistic is obtained by dividing the mean square for each effect by the mean square error term listed at the bottom of the Mean Square column. Column six, labeled "sig," is the P value of the F statistic for each effect. The P value is the probability that the test statistic will take on a value that is at least as high as the observed value of the statistic when the null hypothesis is true. Alternatively, the P value is the smallest level of significance, or α-value, that would lead to rejection of the null hypothesis. The smaller the P value is the greater the importance of the effect. Both sensor and shooter are significant. The interaction of these two factors is also significant.

Tests of Between-Subjects Effects

Dependent Variable: RANK of RESPONSE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
Corrected Model	1791720.000[b]	40	44793.000	14.181	.000	567.225	1.000
Intercept	11728890.0	1	11728890.00	3713.147	.000	3713.147	1.000
SUBJECT	180360.000	29	6219.310	1.969	.003	57.099	.998
SENSOR	470340.000	2	235170.000	74.450	.000	148.901	1.000
SHOOTER	807120.000	3	269040.000	85.173	.000	255.519	1.000
SENSOR * SHOOTER	333900.000	6	55650.000	17.618	.000	105.707	1.000
Error	1007640.000	319	3158.746				
Total	14528250.0	360					
Corrected Total	2799360.000	359					

a. Computed using alpha = .05

b. R Squared = .640 (Adjusted R Squared = .595)

Table I. (U) ANOVA of test factors

(U)   When the interaction is significant, comparisons between the means of the factor sensor may be obscured by the interaction. One approach to this situation is to fix the factor shooter at a specific level and apply a multiple comparison test to the mean of the factor sensor at that level. The results of this analysis are summarized in Table 2. The starred values indicate pairs of means that are significantly different.   For example, this analysis indicates when SHOOTER = 2, there is a statistically significant difference between SENSOR = 3 (fused image) and SENSOR = 1 (visual image), and there is not a statistically significant difference between SENSOR = 3 and SENSOR = 2 (IR image).

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Pairwise Comparisons

Dependent Variable: RANK of RESPONSE

SHOOTER	(I) SENSOR	(J) SENSOR	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
1	1	2	-90.000*	14.511	.000	-118.550	-61.450
		3	-30.000*	14.511	.040	-58.550	-1.450
	2	1	90.000*	14.511	.000	61.450	118.550
		3	60.000*	14.511	.000	31.450	88.550
	3	1	30.000*	14.511	.040	1.450	58.550
		2	-60.000*	14.511	.000	-88.550	-31.450
2	1	2	-138.000*	14.511	.000	-166.550	-109.450
		3	-138.000*	14.511	.000	-166.550	-109.450
	2	1	138.000*	14.511	.000	109.450	166.550
		3	-7.105E-14	14.511	1.000	-28.550	28.550
	3	1	138.000*	14.511	.000	109.450	166.550
		2	7.105E-14	14.511	1.000	-28.550	28.550
3	1	2	6.000	14.511	.680	-22.550	34.550
		3	6.000	14.511	.680	-22.550	34.550
	2	1	-6.000	14.511	.680	-34.550	22.550
		3	-9.948E-14	14.511	1.000	-28.550	28.550
	3	1	-6.000	14.511	.680	-34.550	22.550
		2	9.948E-14	14.511	1.000	-28.550	28.550
4	1	2	-132.000*	14.511	.000	-160.550	-103.450
		3	-24.000	14.511	.099	-52.550	4.550
	2	1	132.000*	14.511	.000	103.450	160.550
		3	108.000*	14.511	.000	79.450	136.550
	3	1	24.000	14.511	.099	-4.550	52.550
		2	-108.000*	14.511	.000	-136.550	-79.450

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table 2. (U) Pair-wise comparisons

(U)   The linear model for this experiment is:

$$y(i,j,k) = \mu + \gamma(i) + \beta(j) + (\tau,\beta)(i,j) + \delta(k) + \varepsilon(\iota,j,k),$$
$$i = 1,2,3 \text{ (visual, IR, fused image respectively)}$$
$$j = 1,2,3,4 \text{ (shooter1, shooter2, shooter3, shooter4)}$$
$$k = 1,2,.....,30 \text{ (subject1, subject2, ...subject30)}$$

where $\tau(i)$ represents the sensor effect, $\beta(j)$ represents the shooter effect, $(\tau,\beta)(i,j)$ is the interaction, $\delta(k)$ is the block effect, and $\varepsilon(i,j,k)$ are independent and identically distributed normal error term.

(U)   The normal probability plot of the residuals is shown in Figure 7. There is no severe indication of non-normality. The plots of the residuals versus each factor and block respectively

give no indication of inequality of variance. These plots are not included in the paper. Thus, we have checked the adequacy of the assumed model.
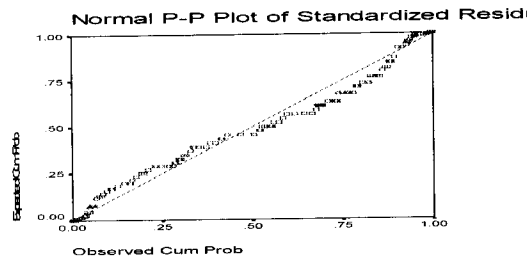

Figure 7. (U) The normal probability plot of the residuals.

(U)   Test No 2

(U)   The second test was performed to find out the subject preference over the quality of the image set. By presenting three sensor images on the screen at the same time, subjects had chances to compare three sensor images directly.   Then they ranked the image set by easier to detect to harder to detect the RPG. Figure 8 shows the result of the first choice of all the subjects. IR image was the first choice that subjects to look at to detect the RPG. The test subjects also commented on the fact that they preferred the fused image, because it had more details.
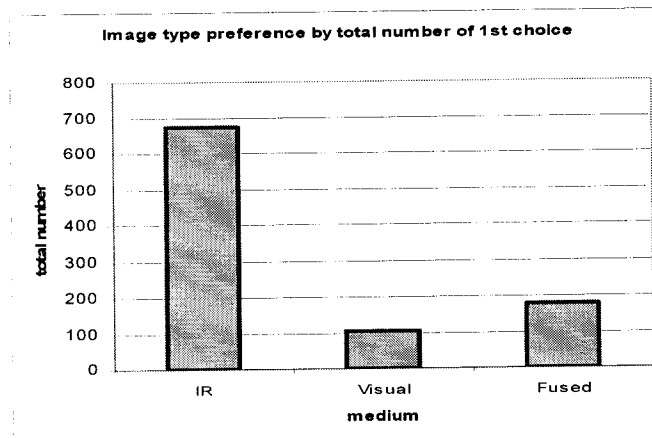

Figure 8. (U) Image quality comparison

(U) Conclusion

(U)   The statistical results of the RPG test were analyzed.   The detection rate of the RPG in the image was analyzed versus the sensor type. Subjects had the highest detection rate of the RPG using the IR sensor, and the lowest detection rate was with the visual image.   In this particular image set, the contrast between the RPG and the background was critical factor of the detection rate difference. Even though the IR image has the higher detection rate for the second

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test, subjects commented on the fact that they preferred to look at the fused image, because it had more details. One of the objectives was to see the relationship between the probability of detection and three metrics. The overall entropy value was not significantly changed over either the sensor type or the shooter type. The clutter and textured clutter metrics traces better to the detection rate (Figure 6.). The highest correlation was between the textured clutter and the probability of detection. The initial data was taken with stereo system. The authors intend in the future to compare the detection rate of three different sensor images by using the 3D image presentation.

(U)   References

(1) Y. Wang, B. Lohmann, "Multisensor Image Fusion: Concept, Method, and Applications," Internet Source.

(2) D. Schmeider and M, Weathersby, Detection performance in clutter with variable resolution, IEEE Trans, Aerosp. Electron. Syst.,AES-19: 1983.

(3) John G. Webster, Wiley Encyclopedia of electrical and electronics engineering, Vol. 10, P215.

(4) SPSS Inc., SPSS Advanced Models 9.0, 1999 manual, p.38 – p.39, and p. 136.